

Standoff Detection of Explosive
Material Molecules, Localized in
Small Areas Nearby Tested Objects

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Presented at **NDIA 19th Annual Security
Symposium**, Reston, MD

June 18, 2003

Motivation

Search for methods of standoff detection of molecules, emitted by explosive materials and localized in small areas nearby tested objects.

Goal

To develop a procedure, which allows to detect the smallest possible concentration of admixture molecules in the air.

Introduction

Standoff localization of admixture molecules, in the air in conditions of cluttered environments, requires for the lidar to consist of a laser operated at wavelengths that coincide with the center of the absorption lines of these molecules.

The minimum concentration of admixture depends on the following factors:

1. Energy of laser emitter at resonant wavelength
2. Absorption cross-section of admixture molecules
3. Sensitivity in the method of measurement of the probe beam phase associated with heating of the air due to absorption of a laser pulse at resonant wavelength

The phase variation is determined by the following expression:

$$\Delta\phi = \frac{S\alpha E_0}{\lambda_r}$$

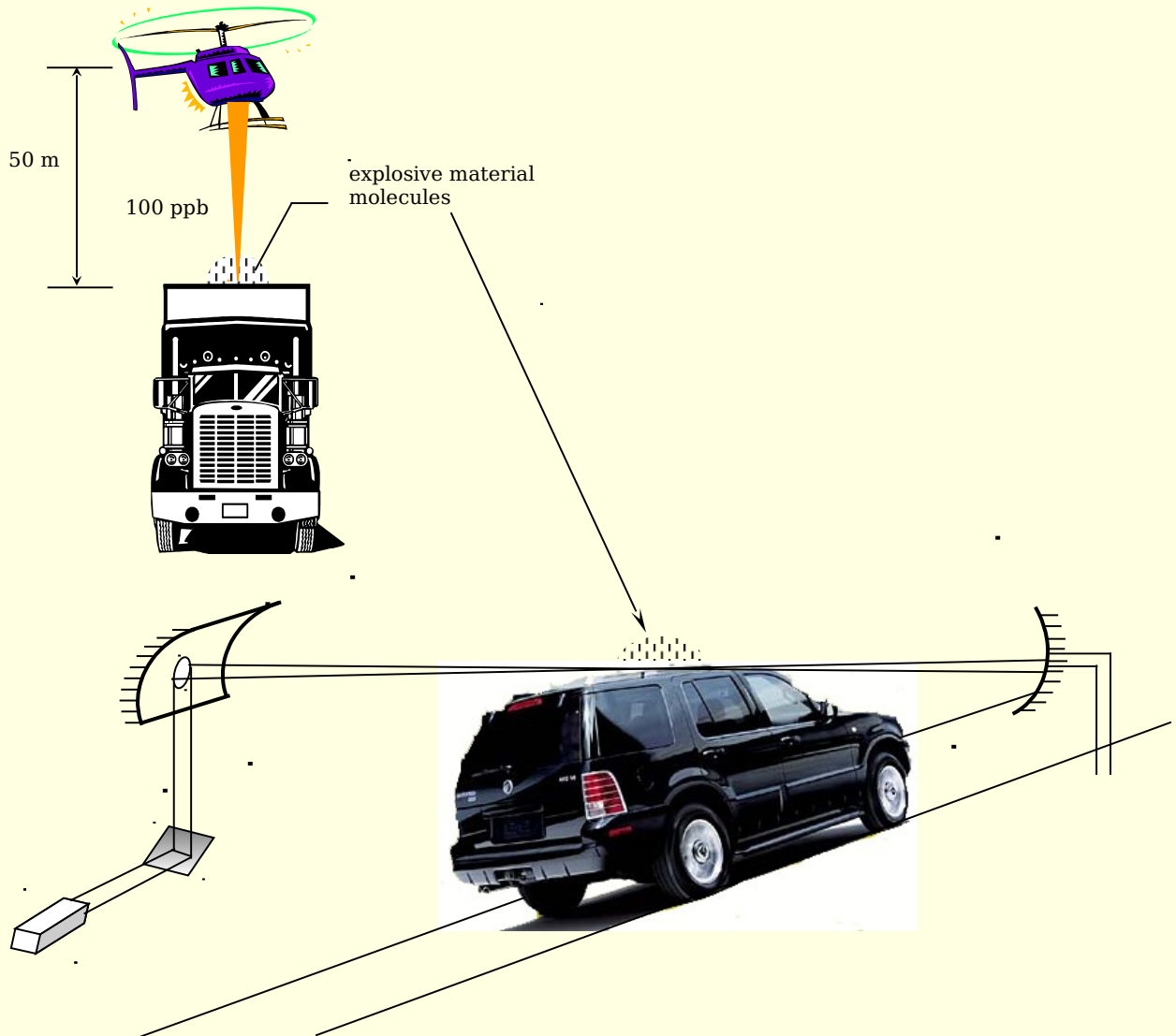
Where S is the parameter that depends on air properties and probe wavelength.

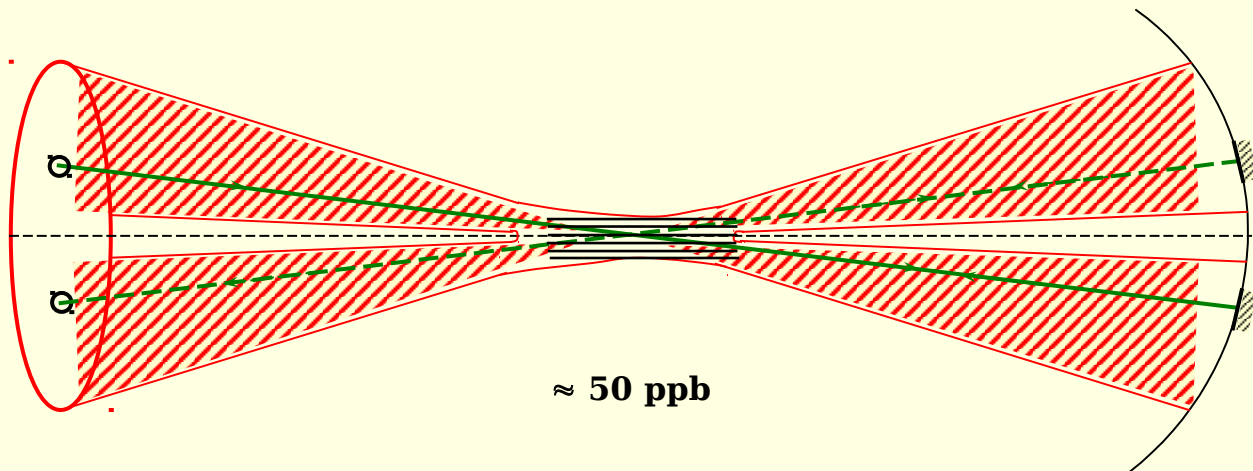
$$S [cm^2, rad/J] = \frac{4\pi (\partial n / \partial T)_P}{C_p \rho \lambda_p}$$

Because of $\alpha = n_a \sigma (\lambda_r)$ we can conclude

$$n_a = \frac{\Delta\phi_{\min} \lambda_r}{S E_0 \sigma(\lambda)}$$

Examples





$$\Delta\phi_{\min} \approx 10^{-3} \pi$$

$$E_0 \sim 5 \text{ mJ}$$

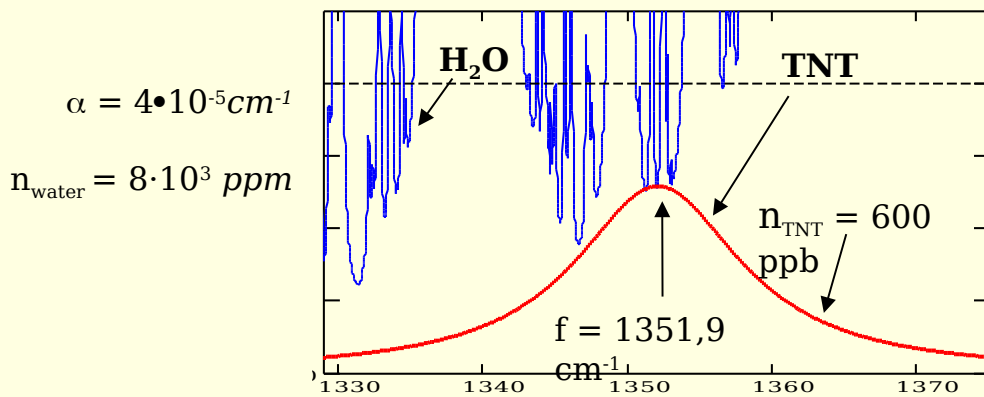
$$\lambda_r = 7.4 \text{ } \mu\text{m}$$

$$\Rightarrow 0.8 \cdot 10^{-6} \text{ cm}^{-1}.$$

*(50 ppb for
TNT)*

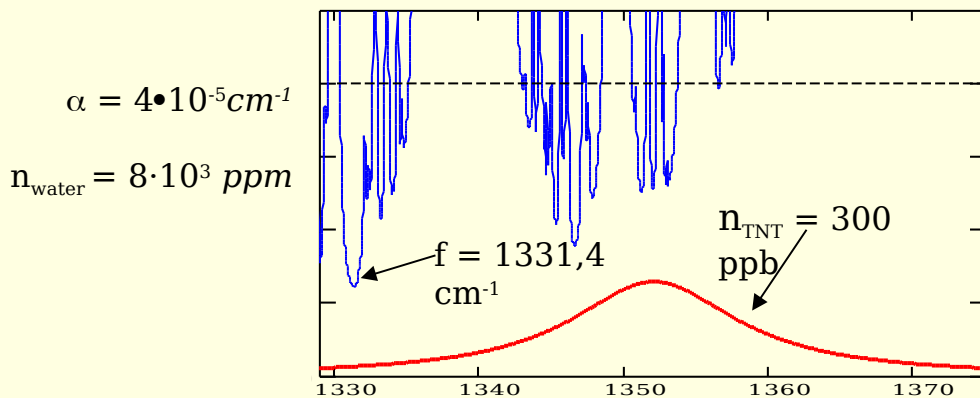
Limitations

The main limitation of sensitivity is connected with the presence of strong H₂O (4-40 thous. ppm) and CO₂ (300 ppm) absorption lines.



Frequency cm⁻¹

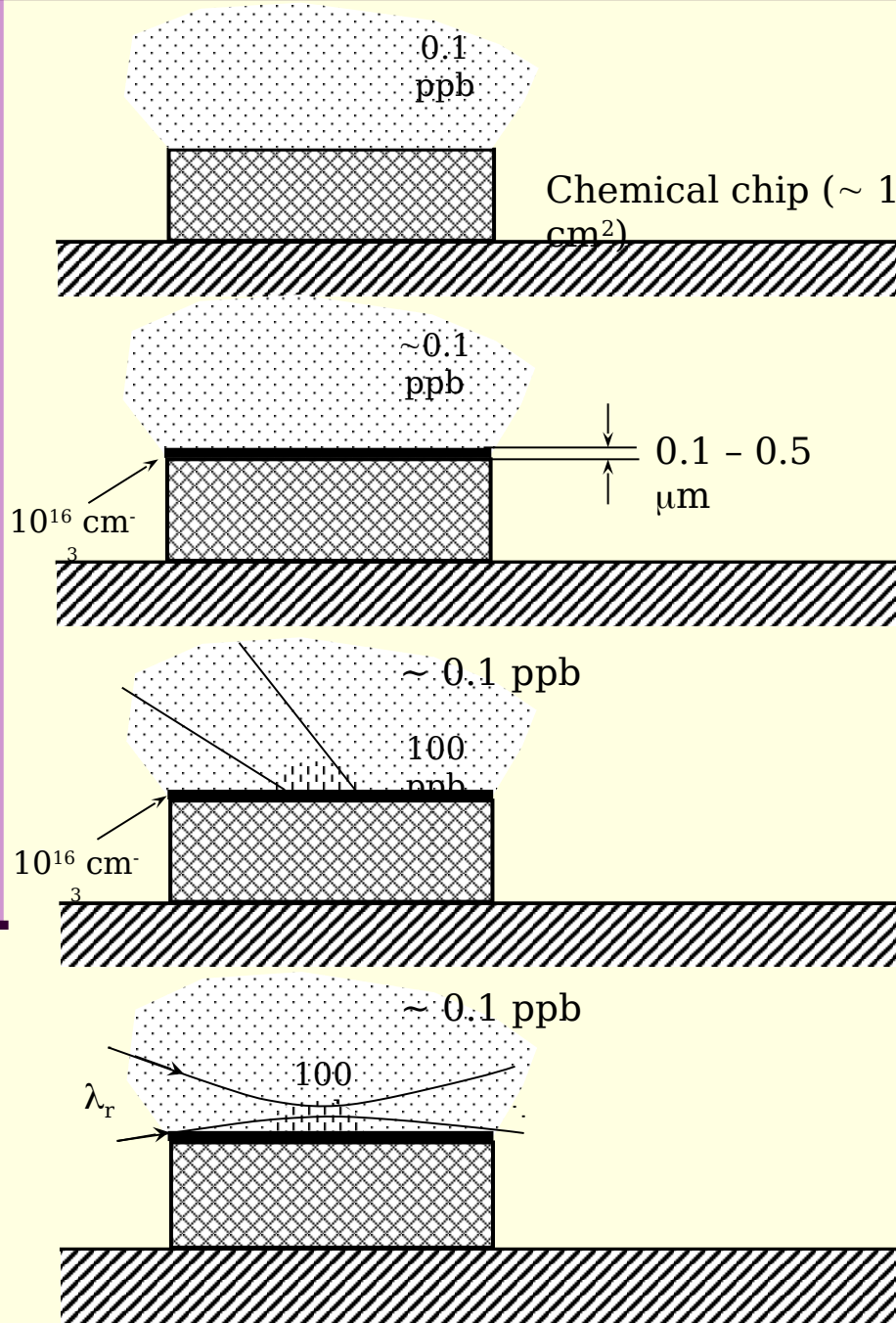
Fig. 2a



Frequency cm⁻¹

Fig. 2b

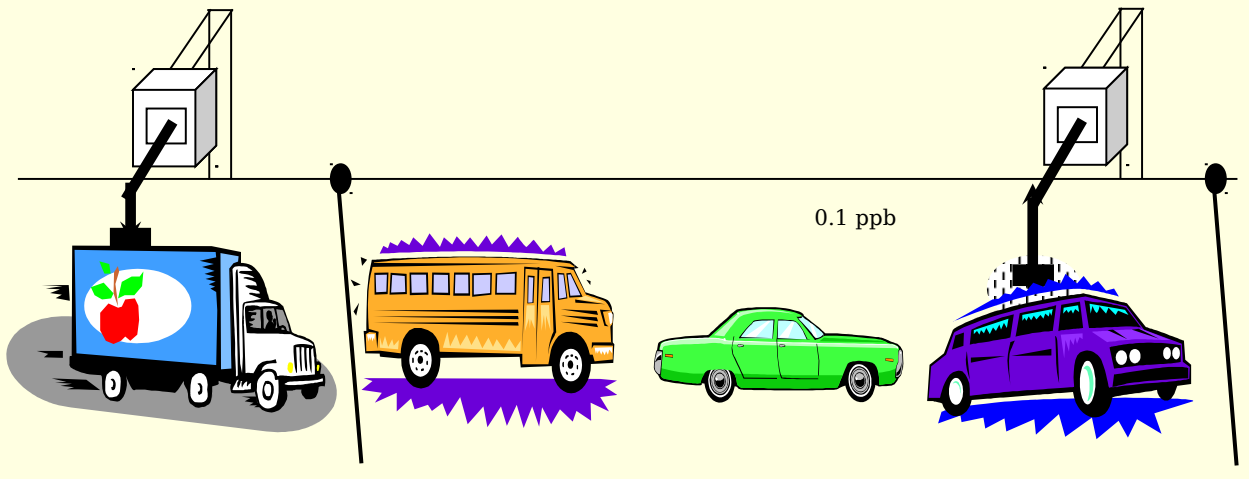
Upgrade detection via laser ablation



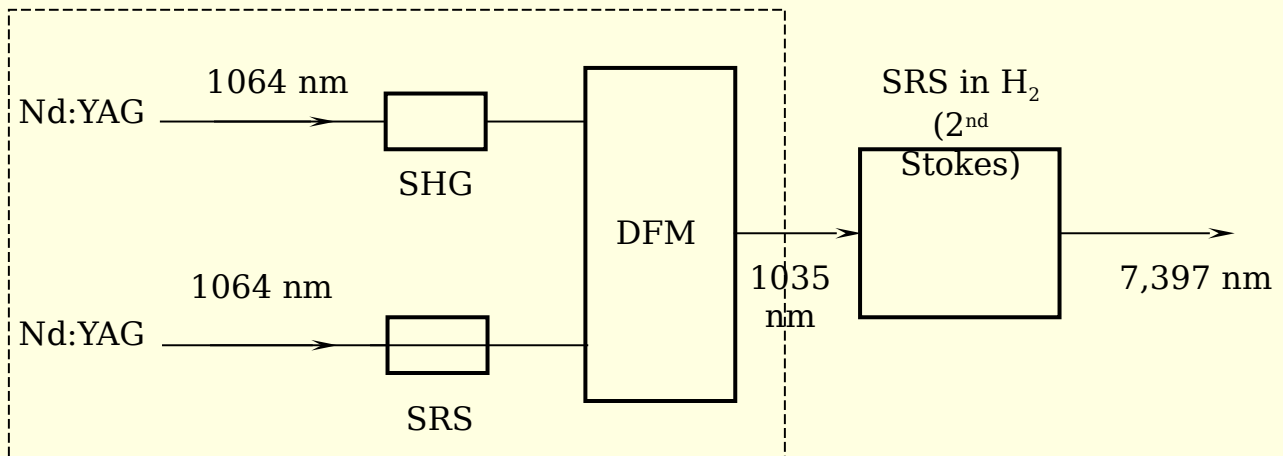
Upgrade detection via laser ablation

Checkpoint for attaching of 1
 cm^2 thin plate

Checkpoint for removing 1
 cm^2 thin plate



Mid IR Lasers at Resonance Wavelength



Conclusion

1. Standoff detection at the level of 300 ppb is limited by water in standard conditions
2. Chemical chip can provide the achievement of sensitivity up to 0.1 ppb or better